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Rest and Activity Patterns of U.S. Army Aviators in Routine and Operational Training Environments

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14. ABSTRACT Fatigue continues to be a leading cause of military aviation mishaps. Several factors, including reversed shift missions, can negatively affect sleep patterns and increase the risk of sleep-related fatigue. The purpose of this descriptive study was to document the rest and activity patterns of U.S. Army aviators in operational training and garrison environments using wristworn actigraphy devices. Results from this study indicate that a substantial proportion of participants in the training environment, even after accounting for small sleep bouts during the day, averaged less than the recommended eight hours of sleep across the recording week. Approximately half of the participants in Garrison received less than eight hours of sleep. Sleep efficiency was relatively high in both groups. Moreover, an informal comparison of light exposure metrics revealed that participants in training were exposed to more light than those in garrison. These results highlight the importance of continued research on aviator sleep in operational environments.												
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Table of Contents

	Page
Introduction.....	1
Phase 1	2
Method.....	2
Participants.....	2
Measures	3
Demographics and medical history questionnaire.	3
Wrist activity monitors.	3
Daily logbook.....	3
Beck Depression Inventory (BDI)..	3
State-Trait Anxiety Inventory (STAI).	3
Pittsburgh Sleep Quality Index (PSQI).....	3
Social Readjustment Rating Scale (SRRS).....	4
Morningness-Eveningness Questionnaire (MEQ).	4
International Physical Activity Questionnaire-short form (IPAQ-short form).	4
Alcohol Use Disorders Identification Test (AUDIT).	4
Procedure..	4
Results.....	5
Self-report data.....	5
Actigraphy.....	6
Sleep efficiency, sleep and wake durations.	6
Light exposure.	8
Phase 1 Discussion.....	9
Phase 2	9
Method.....	9
Participants.....	9
Measures	10
Procedure	10
Results.....	10
Self-report data.....	10
Actigraphy.....	10
Sleep efficiency, sleep and wake durations..	10
Light exposure.	12
Phase 2 Discussion.....	13
General Discussion	13
Conclusions.....	14
References.....	15
Appendix A.....	18
Appendix B. Instruction sheet used by participants to fill out the daily logbook.....	26

List of Tables

Table 1. Phase 1 Data Collection Schedule	5
Table 2. Phase 1 Descriptive Statistics for Self-Report Measures.....	6
Table 3. Phase 1 Descriptive Statistics for Mean Wake Time, Sleep Time, and Sleep Efficiency by Recording Interval	7

Table of Contents (continued)
List of Tables (continued)

	Page
Table 5. Phase 2 Descriptive Statistics for Self-Report Measures.....	10
Table 6. Phase 2 Descriptive Statistics for Mean Wake Time, Sleep Time, and Sleep Efficiency.....	11
Table 7. Phase 2 Light Exposure Descriptive Statistics	12
Table A1. Phase 1 Descriptive Statistics for Flight Duties.....	18
Table A2. Phase 1 Descriptive Statistics for Medial Symptoms and Waivers	19
Table A3. Phase 1 Descriptive Statistics for Health Behaviors.....	20
Table A4. Phase 2 Descriptive Statistics for Flight Duties.....	22
Table A5. Phase 2 Descriptive Statistics for Medial Symptoms and Waivers	23
Table A6. Phase 2 Descriptive Statistics for Health Behaviors.....	24

Table of Figures

Figure 1. Sleep/wake durations (left panel) and sleep efficiency (right panel) by recording interval	7
Figure 2. Light exposure by type and interval	9
Figure 3. Sleep/wake durations (left panel) by recording interval and sleep efficiency (right panel).....	11
Figure 4. Light exposure by type and interval	13

Introduction

Advancements in technology and engineering continue to enhance safety in military aviation, leading to significant reductions in mishaps. Unfortunately, some of the biggest concerns in aviation continue to be problems that have existed for years despite considerable research efforts. According to the Naval Safety Center, fatigue was the second highest causal factor to Class A aviation mishaps (second to spatial disorientation) and the leading cause for all aviation mishaps between 1990-2011 (Hartzler, Chandler, Levin, & Turnmire, 2015; Belland, 2012). Fatigue plays a critical role in mission success due to its impact on vigilance, cognitive function, and overall performance (Banks, Van Donge, Maislin, & Dinges, 2010; Durmer & Dinges, 2005; Van Dongen et al., 2004). While fatigue is deleterious in any military setting, it is especially significant in aviation operations. Fatigue increases the likelihood of mishaps that can potentially lead to loss of life and financial losses over \$10 million dollars for a single accident.

Several factors influence fatigue, many of which are individual differences. Circadian rhythm is the biological clock that functions to regulate sleep drive on an approximately 24-hour cycle (Rogers, Dorrian, & Dinges, 2003). This cycle largely follows the pattern of day and night such that sleepiness is highest during the night. This can make it difficult for aviators to perform optimally when flying reversed shift, night missions common in military operations (Caldwell & Caldwell, 2005). Quality of sleep, rather than simply time in bed, also influences fatigue. Numerous studies have shown fragmented sleep or reduced time spent in slow wave sleep can negatively impact performance measures compared to undisturbed sleep (Gildner, Liebert, Kowal, Chatterji, & Snodgrass, 2014; Miyata et al., 2013; Tonetti, Fabbri, Filardi, Martoni, & Natale, 2015). The large number of interacting variables presents a difficult challenge for studying fatigue in a controlled setting. Consequently, relatively few studies have examined how these various factors influence Soldiers' fatigue levels or sleep patterns in an operational environment.

Of particular importance for military applications is the role of schedules. In an operational setting, there can be frequent schedule changes, shifts alternating between day and night missions, disruptive environmental factors, and other factors that can interfere with aviator sleep patterns. Multiple U.S. military branches have attempted to address these concerns by developing tools to assist in the scheduling of training, shift hours, and blocks of time reserved for sleep (Hursh et al., 2004). At the time of this report, no research is readily available that suggests whether, and if so to what extent, these strategies mitigate safety risk associated with fatigue in an Army aviation operational setting. Although policy and doctrine outline strategies for facilitating adequate rest cycles and provide important information to Soldiers for optimizing sleep and recovery (AR 40-8, AR 95-1, AR 385-90, Leader's Guide to Crew Endurance), these policies generally provide broad guidance (Department of the Army, 2014; 2017; 2018; Blackwell et al., 2015). That is, unit commanders and flight surgeons provide a fatigue avoidance strategy specifically tailored to support individual mission goals. This creates substantial variability in employed strategies, which can be difficult to monitor and enforce. Mission needs and conflicting policies to meet requirements may deprioritize crew rest policies.

Additional external factors can reduce adequate sleep. Noise can have a substantial impact on sleep onset and sleep quality. Proximity to sources of noise such as roadways, airports, or trains can lead to decreases in sleep quality, delayed sleep onset, and diminished performance on reaction time-based tasks (Basner, Muller, & Elmenhorst, 2011; Bodin, Bjork, Ardo, & Albin,

2015). Of particular interest is a recent study that found a 3.5-fold higher increase in sleep disturbance for people living in proximity to a military airfield (Kim et al., 2014). A second factor affecting sleep is temperature. Prior research has shown a decline in core body temperature can facilitate sleep onset and prolong slow-wave sleep (Murphy & Campbell, 1997). Moreover, there is evidence to suggest that lower ambient temperatures can increase sleep duration, sleep efficiency, and morning alertness in those with sleep apnea (Valham, Sahlin, Stenlund, & Franklin, 2012). Light and sleeping surface comfort are two other factors that can negatively affect sleep quality, particularly in a military environment (Azmoon, Dehghan, Akbari, & Sour, 2013; Jacobson, Boolani, Dunklee, Shepardson, & Acharya, 2010). Consideration must also be given to factors Soldiers have control over such as how time allotted for sleep can be spent engaged in personal activities.

The most accurate method of measuring sleep length and sleep quality is with polysomnography (PSG) (Carlson, 2012). However, because PSG involves monitoring subjects with several immobile physiological recording devices and thus restricts subjects to a specific sleep location during observation, PSG is not practical for military operational settings. Actigraphy is a reasonable alternative method for estimating sleep quality and quantity given that it only requires users to wear an accelerometer device (usually on the wrist) to track gross motor movement and other variables such as light exposure. Actigraphy is a valid and reliable measure of sleep and activity levels without the constraints of PSG. Research shows it to be highly accurate in identifying sleep periods, but less reliable in identifying waking bouts during sleep (de Souza et al., 2003; Marino et al., 2013). The low intrusiveness of actigraphy devices also allows sleep and activity patterns to be monitored during extended training periods.

The purpose of this observational study was to estimate and document the sleep quality and quantity of Army pilots in both training and garrison settings using actigraphy. Moreover, self-report measures of sleep and sleep quality were included to augment actigraphy data. This study was structured in two phases. In Phase 1, participants were undergoing operational training exercises. In Phase 2, participants were in garrison. The combination of actigraphy data, questionnaires, and self-report logbooks were expected to provide an accurate depiction of sleep schedules and sleep quality of military aviators in an operational setting.

Phase 1

Method

Participants. Twenty-two Soldiers (20 males, 2 females) from a Combat Aviation Brigade (CAB) at Fort Polk, LA, volunteered to participate in this study. All participants were required to be 18 years of age or older, be Active Duty Service Members, including National Guard or Reserve on orders, be rated pilots currently serving in a CAB unit, and not have a sleeping disorder or a profile that prevented physical activity or flying duties. Study participants were completing operational training exercises at the Joint Readiness Training Center (JRTC) at Fort Polk, LA. Participant ages ranged from 25 to 43 with a mean of 31.14 ($SD = 4.25$) years. Flight experience (on controls time) within the past year ranged from 80 to 300 hr with an average of 130.50 ($SD = 53.97$) hr. Table A1 in Appendix A displays more detailed flight-duty summary statistics. All participants willingly provided their informed consent and completed the study.

Measures. Demographic data (including flight experience) and a brief medical history were collected from participants. Rest and activity data were supplemented with daily logbooks. Additionally, several self-report measures of variables relating to sleep were also collected including depression, anxiety, stress, sleep quality, chronotype, physical activity, and alcohol use.

Demographics and medical history questionnaire. This questionnaire asked participants to report demographic information (age, gender, rank, height, weight, and experience level) medical history data, tobacco use, caffeine and supplement (e.g., multi-vitamins) consumption, and current medications.

Wrist activity monitors. Participants were provided with an Actiwatch Spectrum Plus (Philips Respironics), a small watch-like device worn on the wrist that utilizes an accelerometer (32 Hz sampling rate) to monitor the magnitude of participant motion. These watches contain an omnidirectional sensor, which integrates the degree and speed of motion and produces an electrical current that varies in proportional magnitude to the movement of the device. Data analysis with the Actiware software (Version 6.0.9) identifies four recording intervals (sleep, rest, active, daily) and exports summary statistics for measures of wake and sleep durations (in minutes), sleep efficiency (defined as the ratio of sleep time to the sum of wake time plus sleep time for sleep intervals), white light exposure (in lux-min) and color light exposure (in $\mu\text{W}/\text{cm}^2$) for each recording interval over the recording period. Data are logged at 1 min epochs.

Daily logbook. The daily logbook was developed in-house with the purpose of collecting daily entries (similar to a sleep diary) on sleep/wake times, sleep quality, flight duties (start time and duration), and daily tobacco, caffeine, and supplement use. The purpose of the logbook data was to facilitate interpretation of data from the wrist activity monitor. Participants were provided with a template sheet containing all of the information to be recorded each day (Appendix B).

Beck Depression Inventory (BDI). Depressive symptoms were measured using the Beck Depression Inventory-II (BDI-II) (Beck, Steer, & Brown, 1996). The BDI-II is a commonly used 21-item, multiple-choice self-report that captures affect, cognitions, and physical symptoms of depression over the previous two weeks. Higher total scores indicate greater endorsement of depression symptoms.

State-Trait Anxiety Inventory (STAI). The STAI is a 40-item, self-report anxiety inventory rated on a 4-point Likert scale that captures two types of anxiety: state, or event-dependent anxiety, and trait, or persistent demonstrations of anxiety as a personal characteristic (Spielberger, 1983). Anxiety scores on the STAI are calculated by reverse-coding select responses and then summing the total point values of the items. Higher scores indicate higher levels of anxiety for both of the subscales.

Pittsburgh Sleep Quality Index (PSQI). The PSQI is a 10-item self-report scale of sleep quality over the past 30 days (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI consists of seven component scores, with subscale scores ranging from zero to three: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction. Component scores are summed to give a global score of

subjective sleep quality, ranging from 0 to 21, with higher scores representing poorer sleep quality.

Social Readjustment Rating Scale (SRRS). The SRRS (Holmes & Rahe, 1967) is a list of 43 common, stressful life events shown to relate to overall illness. Participants indicate which events have occurred in their life within the last year. Events are assigned a point value based on how strongly they are thought to contribute to illness, and scores are calculated by summing the weights of all selected events. Higher scores indicate a greater likelihood of becoming ill. Scores less than or equal to 150 indicate low stress. Scores 150-299 indicate a 50% chance of getting sick in the near future and scores equal to or greater than 300 indicate an 80% chance of getting sick in the near future.

Morningness-Eveningness Questionnaire (MEQ). The Horne and Östeberg Morningness-Eveningness questionnaire (MEQ) (Horne & Östeberg, 1976) is a 19-item questionnaire that asks participants to rate questions regarding preferred sleep and wake times. Scores range 16 to 86, with scores of 41 and below indicating “evening types,” scores of 59 and above indicating “morning types,” and scores between 42 and 58 indicating “intermediate types.”

International Physical Activity Questionnaire-short form (IPAQ-short form). The seven-item IPAQ-short form estimates one’s level of physical activity during the last seven days (Booth 2000). Questions ask about the frequency and duration of walking, moderate-intensity activity, and vigorous physical activity defined as requiring high physical effort and increased breathing that persisted longer than 10 minutes. Algorithms for processing the data classify the participant into one of three categories: low, moderate, or high.

Alcohol Use Disorders Identification Test (AUDIT). The AUDIT is a 10-question assessment of alcohol consumption to identify hazardous drinking, harmful drinking, or alcohol dependence (Daepfen, Yersin, Landry, Pécoud, & Decrey, 2000; Donovan, Kivlahan, Doyle, Longabaugh, & Greenfield, 2006). With the use of an included scale to define alcohol units, participants indicate on a scale of 0-4 how often they engage in a specified activity or how often a description applies to them. Scores for each item are summed together to form a total score, with higher total scores indicating a higher level of risk for alcohol-related problems.

Procedure. The U.S. Army Medical Research and Materiel Command Office of Research Protections Institutional Review Board reviewed and approved the protocol for this study. All procedures were conducted according to institutional ethical standards. Data collection for the study occurred at the JRTC. Potential volunteers were briefed in a group setting during a time chosen by leadership to limit interference with the training schedule. No supervisors were present during the briefing.

Table 1 displays an overview of the data collection procedures. Volunteers interested in participating provided consent and were assigned a wrist activity monitor with a randomly assigned identification number, a logbook, and instructions for how to complete daily entries into the logbook. Once the wrist activity monitors were placed on the participants, each individual was then provided a questionnaire packet to complete that included the questionnaires described above. Following completion of the questionnaire packet, participants returned the packet to the study team and were then released back to their training leadership. Each participant wore the wrist activity monitor continuously for one week and filled out the logbook each day as time

permitted. After one week, the study team returned to the data collection site to retrieve the wrist activity monitors, logbooks, and administer a second copy of the questionnaire packet (excluding demographics and medical history).

Table 1. Phase 1 Data Collection Schedule

Day of Study Period	Tasks / Tests
Day 1	Wrist watch distribution; Demographics & Medical History Questionnaire
Day 1 & Day 8	Beck Depression Inventory (BDI)
	International Physical Activity Questionnaire-short form (IPAQ- short form)
	Pittsburg Sleep Quality Index (PSQI)
	Social Readjustment Rating Scale (SRRS)
	State-Trait Anxiety Inventory (STAI)
	Morningness-Eveningness Questionnaire (MEQ)
Day 1 – Day 8	Alcohol Use Disorders Identification Test (AUDIT)
	Wrist Activity Monitor and logbook

Note: The demographics and medical history questionnaires were collected once at the beginning of the the collection period. The questionnaires (excluding demographic and medical history) were administered at the beginning and end of data collection.

Results

Self-report data. Participant medical history (Table A2), tobacco use, caffeine and supplement consumption (Table A3), and descriptive statistics are displayed in Appendix A. The most frequent medical symptoms reported were experiencing car, train, sea, simulator, or airsickness ($n = 5$) and anxiety or depression ($n = 5$). A majority of participants ($n = 18$) reported daily caffeine use. Participants reported an average flight duration of 2.70 hr ($SD = 0.78$). Three participants did not complete questionnaires at Day 8. Descriptive statistics for the BDI, STAI, PSQI, SRRS, MEQ, IPAQ, and AUDIT for both data collections are displayed in Table 2. Notably, of the valid MEQ responses at Day 1, all participants were classified as either definite morning ($n = 1$), moderate morning ($n = 11$), or intermediate ($n = 9$) chronotypes. Moreover, of the valid IPAQ responses, 79% ($n = 15$) of participants were classified as highly active.

A majority of participants reported completing the logbooks as being a burden to their

training duties resulting in limited responses. Therefore, these data were excluded from further analysis.

Table 2. Phase 1 Descriptive Statistics for Self-Report Measures

Time 1 Variable	<i>n</i>	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>Min</i>	<i>Max</i>
BDI	20	9.35	8.65	6.50	0.00	25.00
STAI- State	21	17.90	5.62	18.00	10.00	27.00
STAI- Trait	20	32.95	11.53	29.50	20.00	57.00
SRRS	22	173.64	95.67	185.50	25.00	394.00
MEQ	21	59.14	7.53	59.00	44.00	75.00
AUDIT	22	6.18	5.27	4.50	0.00	20.00
PSQI	22	6.43	3.37	5.25	2.00	14.50
IPAQ	19	4,985.63	3,494.75	3,770.00	587.00	14,718.00
Time 2 Variable						
BDI	19	8.42	7.59	7.00	0.00	30.00
STAI- State	19	34.16	10.20	32.00	20.00	59.00
STAI- Trait	18	31.33	10.98	27.00	21.00	57.00
SRRS	19	203.63	103.60	218.00	12.00	386.00
MEQ	15	57.40	8.19	57.00	42.00	74.00
AUDIT	16	6.63	4.88	5.50	0.00	16.00
PSQI	18	8.03	4.10	7.25	3.00	18.00
IPAQ	14	8,030.43	4,464.16	7,164.00	960.00	14,718.00

Actigraphy. The Actiware analytic software exports outcome measures from continuously recorded data aggregated for each day by interval type (rest, active, sleep, daily) and then averaged across the recording week. It should be noted that sleep intervals are a subset of rest intervals. Therefore, rest intervals include sleep interval observations. One participant failed to return their Actiwatch and one participant did not wear the Actiwatch for the required duration of the study. These participants were excluded from actigraphy analyses, resulting in a usable sample size of 20 for these data. The median was used to describe the central tendency of distributions that significantly deviated from normality.

Sleep efficiency, sleep and wake durations. Table 3 displays descriptive statistics for sleep efficiency and sleep/wake durations by recording interval. Mean sleep durations during sleep intervals across the recording week ranged from 321.57 min (5.36 hr) to 547.00 min (9.12 hr) with an average duration of 384.19 min (6.40 hr). Participants averaged 84.94% (SD = 4.24%) sleep efficiency. Median wake duration for active intervals was 816.44 min (13.61 hr). At the daily level, participants, on average, spent about twice as much time awake than sleeping. Boxplots for these data are displayed in Figure 1 with individual mean observations across the recording week plotted. Importantly, 95% ($n = 19$) of participants averaged less than 8 hr of

sleep per week during sleep intervals and 70% ($n = 14$) of participants averaged more than 13 hr of active wake time during the week during active intervals. Even after accounting for smaller bouts of sleep using daily interval data, 90% ($n = 18$) of participants did not average 8 hr of sleep per day during the week. Additionally, 70% ($n = 14$) of participants averaged wake times exceeding 13 hr per day.

Table 3. Phase 1 Descriptive Statistics for Mean Wake Time, Sleep Time, and Sleep Efficiency by Recording Interval

Variable	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>Min</i>	<i>Max</i>
Wake Time (min)					
Rest	59.80	19.49	56.64	36.83	128.80
Active	847.79	115.39	816.44	692.89	1116.83
Sleep	51.76	18.27	48.75	34.14	116.40
Daily	818.91	61.23	827.63	672.33	946.50
Sleep Time (min)					
Rest	398.48	55.64	379.64	339.80	569.40
Active	132.58	83.04	119.14	27.11	354.67
Sleep	384.19	53.67	367.75	321.57	547.00
Daily	431.45	51.32	425.62	313.00	563.25
Sleep Efficiency (%)					
Sleep	84.94	4.24	84.16	77.87	96.20

Note. $N = 20$

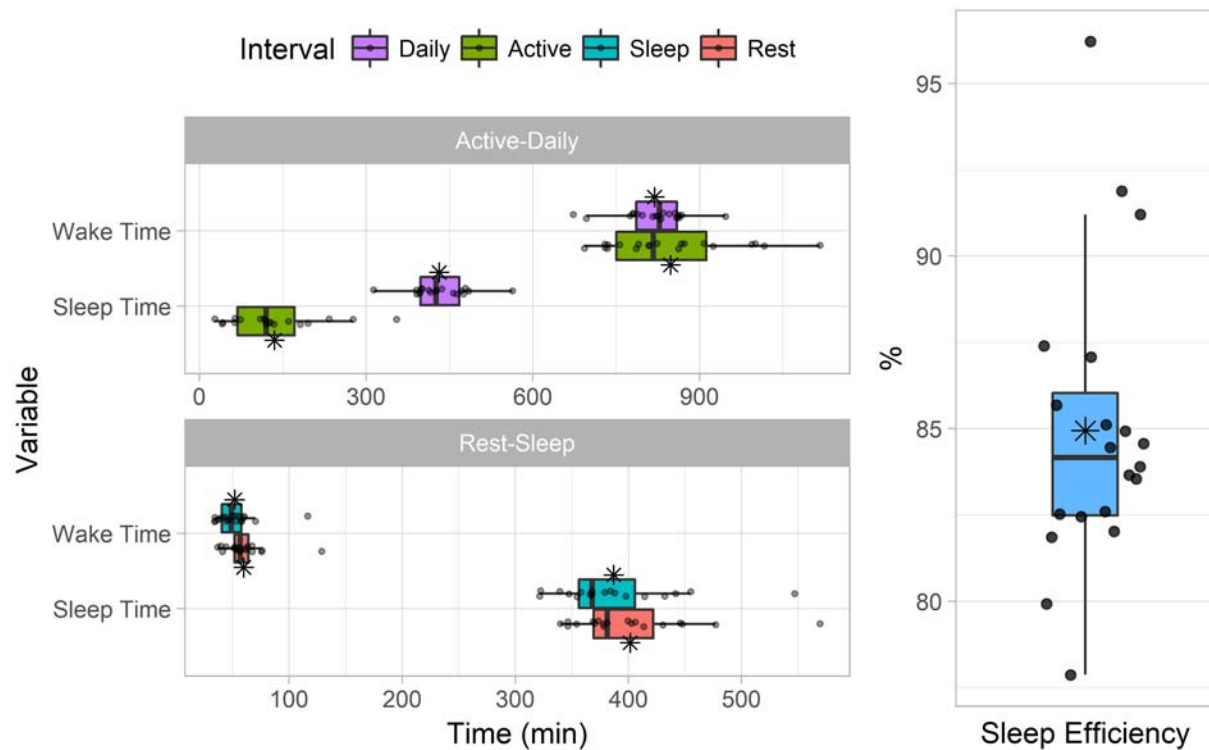


Figure 1. Sleep/wake durations (left panel) and sleep efficiency (right panel) by recording

interval. Individual weekly means are plotted as dots. *Indicates the mean.

Light exposure. Table 4 displays descriptive statistics for light exposure metrics by recording interval and Figure 2 displays boxplots for these data. Distributions of light exposure were positively skewed and quite variable. Examining median colored light exposure values revealed that red light exposure predominated followed by green and blue light for all recording intervals. Excluding daily intervals, active intervals were characterized by more light exposures across all light types, followed by rest and sleep intervals, respectively.

Table 4. Phase 1 Light Exposure Descriptive Statistics by Interval

Variable	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>Min</i>	<i>Max</i>
White Exposure (lux-min)					
Rest	17,904.27	41,128.46	1,377.80	0.24	166,299.30
Active	239,359.30	188,682.64	214,193.40	46,632.72	716,390.50
Sleep	17,381.84	39,714.03	1,319.28	0.01	159,586.80
Daily	231,203.01	180,198.04	173,819.85	40,804.15	663,514.30
Red Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	30,163.21	75,609.80	1,790.00	1.06	328,000.00
Active	393,785.00	341,607.41	287,000.00	84,500.00	1,300,000.00
Sleep	28,727.10	70,753.01	1,715.00	0.20	305,000.00
Daily	383,065.00	340,061.68	292,500.00	83,300.00	1,300,000.00
Green Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	31,998.78	92,461.29	1,580.00	0.45	411,000.00
Active	284,315.00	258,940.31	192,500.00	48,400.00	949,000.00
Sleep	30,953.12	88,754.41	1,525.00	0.00	394,000.00
Daily	285,510.00	282,623.72	183,000.00	42,300.00	1,070,000.00
Blue Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	18,859.93	48,253.56	1,029.00	0.17	208,000.00
Active	180,865.00	153,220.59	125,000.00	29,200.00	567,000.00
Sleep	18,366.50	46,743.54	990.50	0.00	201,000.00
Daily	179,665.00	158,649.91	120,500.00	25,500.00	551,000.00

Note. $N = 20$

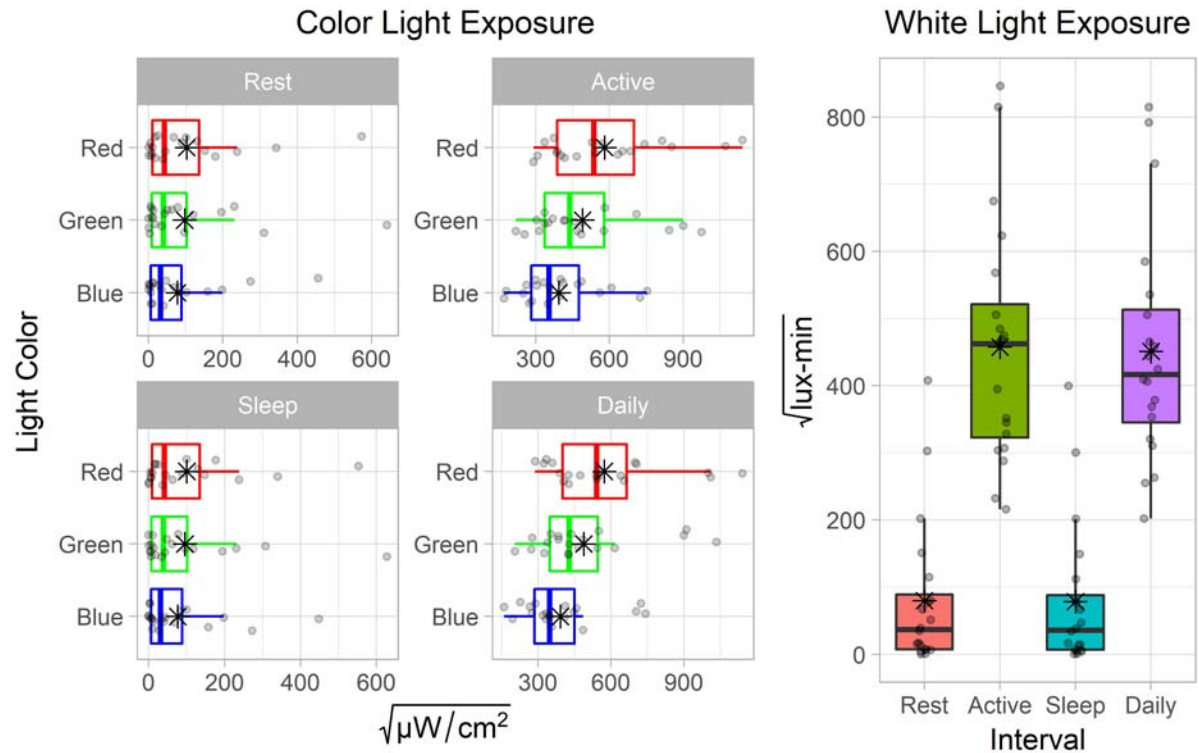


Figure 2. Light exposure by type and interval. Individual observations are plotted as dots. Units are square root transformed to reduce figure distortion. *Indicates the mean.

Phase 1 Discussion

Phase 1 revealed that in the training environment, 95% of participants averaged less than 8 hr of sleep during sleep intervals and 70% of participants averaged 13 hr or more of active wake time. After accounting for sleep across other intervals, 90% of participants still averaged less than 8 hr of sleep. This indicates that little to no additional time besides the time allocated to extended sleep is available for short naps or, if available, was used for this purpose. Despite this limited sleep time, participants in the training environment achieved a relatively high sleep efficiency during sleep intervals (i.e., a large proportion of time sleeping while in bed), potentially offsetting the limited sleep time. Light exposure data revealed a high amount of variation and positively skewed distributions. For color light, participants were predominately exposed to red light across the recording intervals followed by green and blue light, respectively. Additionally, Phase 1 revealed that the self-report logbooks interfered with participants performing their mission duties during training. Therefore, a less intrusive means of collecting self-report data to corroborate actigraphy data in operational environments is recommended for future research.

Phase 2

Method

Participants. Ninety-nine garrison-stationed Soldiers from Fort Bragg, NC and Fort

Rucker, AL were initially recruited to participate in Phase 2. Of this initial sample, 15 participants were excluded for not meeting flight requirements, resulting in a sample size of 84 (78 males and 6 females). Ten participants who participated in Phase 2 also participated in Phase 1. Seventy-three of the participants were from Fort Bragg. Participant ages ranged from 23-57 years with an average age of 32.55 ($SD = 6.74$) years. Flight experience (on controls time) within the past year varied substantially from 14 hr to 450 ($M = 133.13$, $SD = 74.77$) hr. On average, participants flew 2.84 ($SD = 6.60$) flights within the past three months with an average duration of 3.08 ($SD = 1.12$) hr.

Measures. For Phase 2, participants only completed four questionnaires: demographics and medical history, AUDIT, BDI, and the Epworth Sleepiness Scale (ESS). The demographics and medical history, AUDIT, and BDI were the same as described in Phase 1. The Epworth Sleepiness Scale (Johns, 1991) is an eight-item questionnaire that measures daytime sleepiness. Items ask participants to rate their chance of dozing off during common daily activities. Higher total scores indicate greater daytime sleepiness. The same Actiwatch devices as described in Phase 1 were used in Phase 2.

Procedure. Participants were first briefed on Actiwatch procedures and assigned a watch to wear for one week. After Actiwatch distributions, participants completed the demographics and medical questionnaire, AUDIT, BDI, and ESS. These questionnaires were completed only once. After the one-week period, participants returned their Actiwatches to the research team.

Results

Self-report data. Descriptive statistics for medical information (Table A3), tobacco use, caffeine consumption, and supplement consumption (Table A6) are displayed in Appendix A. Briefly, The most frequent medical symptoms reported were frequent or severe headache ($n = 10$) and experiencing car, train, sea, simulator, or air sickness ($n = 9$). Fifty-five participants reported using caffeine daily. Descriptive statistics for the AUDIT, BDI, and ESS are displayed in Table 5.

Table 5. Phase 2 Descriptive Statistics for Self-Report Measures

Variable	<i>n</i>	<i>M</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
BDI	84	3.84	4.51	0.00	25.00
ESS	84	5.73	2.98	1.00	13.00
AUDIT	83	3.74	2.67	0.00	12.00

Actigraphy. Data processing and analytics were conducted the same way as in Phase 1. Seven participants did not wear the Actiwatch for a sufficient amount of time during the recording week. These participants were excluded, resulting in a useable sample size of 77 for actigraphy data.

Sleep efficiency, sleep and wake durations. Table 6 displays descriptive statistics for average sleep efficiency and sleep/wake durations by recording interval. Figure 3 displays boxplots for these data with individual mean observations plotted. Mean sleep durations during sleep intervals across the recording week ranged from 251.60 min (4.19 hr) to 568.00 min (9.47

hr) with an average of 410.47 min (6.84 hr) and 83.18% sleep efficiency. Importantly, during sleep intervals, 92.21% ($n = 71$) of participants averaged less than 8 hr of sleep. However, when accounting for sleep obtained during other intervals (i.e., at the daily level), participants averaged 8.04 hr of sleep, with 49.35% ($n = 38$) averaging less than 8 hr of sleep during the week. During defined active intervals, participants were awake for an average of 684.07 min (11.40 hr). Additionally, 14.29% ($n = 11$) averaged more than 13 hr of wake time during active intervals. At the daily level, participants spent approximately 5.76 more hours awake than asleep.

Table 6. Phase 2 Descriptive Statistics for Mean Wake Time, Sleep Time, and Sleep Efficiency ($N = 77$).

Variable	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>Min</i>	<i>Max</i>
Wake Time (min)					
Rest	63.60	22.69	58.43	33.50	183.14
Active	684.07	90.23	677.86	475.43	935.17
Sleep	51.87	21.51	47.43	20.25	170.86
Daily	755.89	95.27	765.75	456.13	922.43
Sleep Time (min)					
Rest	430.80	55.49	431.71	284.00	584.50
Active	94.86	33.98	88.13	22.75	177.29
Sleep	410.47	56.86	415.57	251.60	568.00
Daily	482.37	82.96	484.00	260.60	672.86
Sleep Efficiency (%)					
Sleep	83.18	5.59	84.71	63.38	90.77

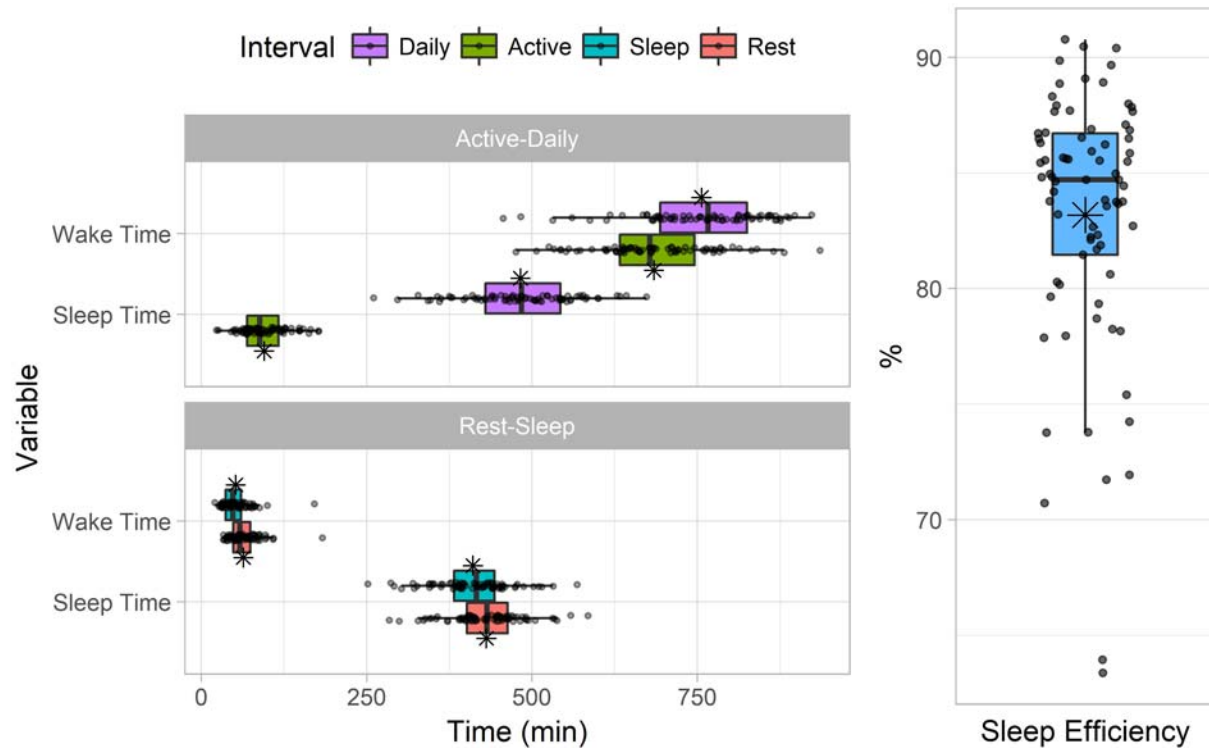


Figure 3. Sleep/wake durations (left panel) by recording interval and sleep efficiency (right panel). Individual weekly means are plotted as dots. *Indicates the mean.

Light exposure. Table 7 displays descriptive statistics for mean light exposure by light type and recording interval, and Figure 4 displays boxplots for the data. Trends in light exposure data were similar to Phase 1. Distributions were positively skewed with high variability. In terms of color light exposure, red light exposure predominated the recording intervals followed by green and blue light, respectively. Participants were also exposed to more light during active intervals than rest and sleep intervals.

Table 7. Phase 2 Light Exposure Descriptive Statistics

Variable	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>Min</i>	<i>Max</i>
White Exposure (lux-min)					
Rest	726.21	2,987.99	44.46	0.00	23,086.46
Active	123,843.63	72,173.43	103,462.20	6,094.18	411,266.20
Sleep	615.25	2,917.45	19.66	0.00	23,084.56
Daily	127,467.30	73,433.82	108,864.20	6,094.99	411,277.60
Red Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	957.67	4,672.37	136.00	0.00	40,500.00
Active	220,325.97	163,784.19	177,000.00	11,800.00	847,000.00
Sleep	849.11	4,655.20	51.00	0.00	40,400.00
Daily	226,301.30	170,489.29	186,000.00	11,800.00	967,000.00
Green Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	737.50	3,373.84	79.50	0.00	28,300.00
Active	134,483.64	94,412.39	112,000.00	5,440.00	560,000.00
Sleep	666.86	3,366.77	26.80	0.00	28,300.00
Daily	138,030.39	97,408.24	116,000.00	5,440.00	640,000.00
Blue Exposure ($\mu\text{W}/\text{cm}^2$)					
Rest	414.57	1,596.90	50.70	0.00	12,500.00
Active	80,632.21	52,679.29	66,200.00	4,080.00	275,000.00
Sleep	362.44	1,580.39	21.30	0.00	12,500.00
Daily	82,550.39	52,909.98	70,800.00	4,080.00	315,000.00

Note. $N = 77$

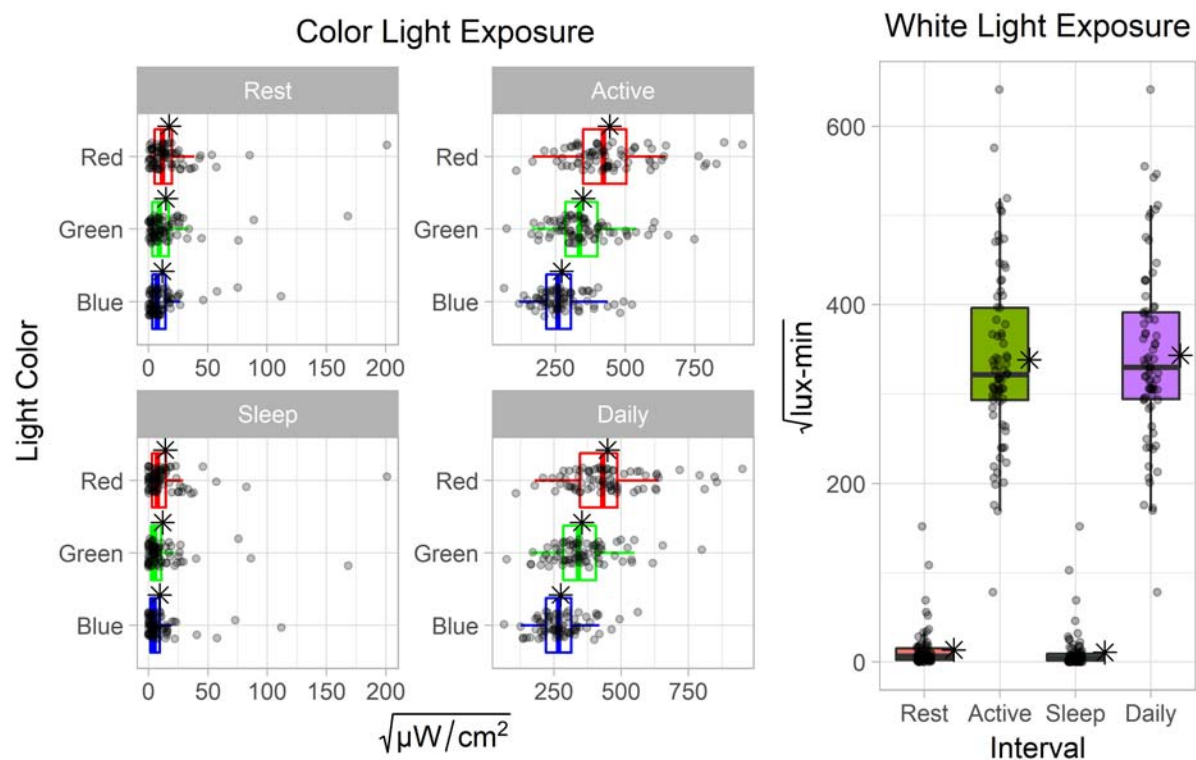


Figure 4. Light exposure by type and interval. Individual observations are plotted as dots. Units are square root transformed to reduce figure distortion. *Indicates the mean.

Phase 2 Discussion

Phase 2 revealed a majority of participants received less than eight hours of sleep during sleep intervals over the course of the measurement week. However, when factoring in smaller bouts of sleep throughout the day (i.e., naps during rest periods) approximately half of the participants received less than eight hours of sleep. Only a minority of participants averaged more than 13 hr of wake time during the measurement week. During sleep intervals, participants spent almost 85% of their time in bed actually asleep. These results indicate aviators in the garrison environment are afforded and/or use more time for short sleep periods throughout the day, allowing some aviators to reach an average of eight hours of sleep per day. As with Phase 1, participants were exposed to more red light across the four recording intervals, followed by green and blue light, respectively.

General Discussion

This study sought to document the sleep and wake patterns of Army aviators in training and garrison environments using wrist-worn actigraphy devices. Although no formal inferential statistical tests were conducted, participants in garrison generally spent more time sleeping and had more time during rest intervals to nap than those in the training environment. Examining strictly sleep intervals, 95% of participants in the training group and 92% participants in the garrison group averaged less than eight hours of sleep per day during the recording week. When factoring in additional sleep from shorter rest periods, 90% of participants in the training group averaged less than eight hours of sleep compared to 49% of garrison participants. This likely reflects more opportunities for garrison-stationed aviators to nap compared to those in the

training environment. The sleep duration results obtained for the training group in this study are similar to those obtained in deployed, non-aviator Army combat samples (LoPresti et al., 2016). On average, LoPresti and colleagues reported Army combat patrols in Afghanistan received between five to six hours of sleep per day. More importantly, approximately half of the Soldiers reported that when they made a mistake affecting mission outcomes, sleepiness was the main cause. This same sleep pattern, when translated to the highly demanding aviation environment, significantly reduces performance and mission effectiveness (e.g., Banks et al., 2010).

Additionally, light exposure across all light types was greater in the training environment than in garrison. Light influences the circadian timing in humans, with extended nocturnal light exposure negatively affecting health outcomes such as sleep duration (e.g., de la Iglesia et al., 2015). Moreover, there is evidence to suggest that prolonged blue light exposure prior to sleep can alter brain electrophysiological activity and shorten rapid eye-movement sleep (Münich et al., 2006). The light data obtained from this study suggest that the training environment might pose a risk to Army aviators for light-related disruptions in sleep (relative to the garrison environment). However, further research with more experimental control is needed to determine the effects of light exposure in the training environment on aviator sleep and subsequent performance outcomes.

One limitation of this study is that the exact cause (other than a rigorous training schedule) of decreased sleep duration in the training environment is not specifically known. A number of factors can influence sleep durations over the course of training beyond just a demanding training schedule. The data collected for this study only give a “top-down” view of sleep patterns and durations. The daily logbooks developed for this study attempted to achieve this goal, but significantly interfered with training and participants were subsequently non-compliant. The use of a minimally invasive subjective measure of sleep quality and duration to augment actigraphy data in the training environment would aid in understanding sleep disturbances.

Another limitation was the relatively small sample of participants in training compared to garrison. Although no inferential statistics were conducted to examine group differences, a larger training sample would stabilize data variability. Finally, only one measure of sleep quality (sleep efficiency) was obtained during the study period. Sleep quality is a multidimensional construct that is difficult to capture in a single measure (Krystal & Edinger, 2008). More measures of sleep quality would provide a more holistic picture of aviator sleep quality.

Conclusions

The results of this study reinforce the notion that operational environments strain sleep durations in Army aviators. Furthermore, opportunities for and/or use of shorter sleep periods throughout the day in operational environments appear to be less than those available in the garrison environment. Future research should employ a minimally intrusive subjective measure of sleep quantity and quality to assess causes for significant sleep reductions in operational training environments. Additionally, the light exposure results of this study potentially warrant future investigations into the effects of increased light exposure during operational training on sleep quality and aviator performance.

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Appendix A

Table A1. Phase 1 Descriptive Statistics for Flight Duties

Variable	<i>n</i>	Mean	SD	Min	Max
On the controls time (last year)	22	130.50	53.97	80.00	300.00
On the controls time (last 90 days)	22	41.91	22.77	7.00	90.00
On the controls time (last 30 days)	22	18.86	8.77	3.00	40.00
^a How many hours do you fly for military related duties?	22	18.82	44.02	2.00	200.00
^a How many hours do you fly for military related duties? (simulated)	22	6.26	16.87	0.00	80.00
^a How many hours do you work?	22	29.89	25.24	8.00	70.00
^a How many flights do you perform?	22	2.16	1.50	1.00	6.00
^a Average length of a typical flight (hours)	22	2.70	0.78	2.00	4.00
^a What percentage of your military flying occurs during: Day	22	45.86	19.49	10.00	80.00
^a What percentage of your military flying occurs during: Night unaided	21	10.02	8.67	1.00	39.00
^a What percentage of your military flying occurs during: Night with NVGs	22	44.50	19.70	1.00	85.00

Note. ^a indicates data were obtained from the preceding three months.

Table A2. Phase 1 Descriptive Statistics for Medial Symptoms and Waivers

Variable	<i>n</i>	Frequency
Frequent or Severe Headache	22	Yes = 4 No = 18
Car, Train, Sea, Simulator, or Air Sickness	22	Yes = 5 No = 17
A Period of Unconsciousness or Concussion	22	Yes = 3 No = 19
Have you had a recent sinus infection	22	Yes = 2 No = 20
Anxiety or depression	22	Yes = 5 No = 17
Been issued a waiver for behavioral health	22	Yes = 1 No = 21
Been grounded for a medical condition	21	Yes = 2 No = 19

Table A3. Phase 1 Descriptive Statistics for Health Behaviors

Variable	<i>n</i>	Freq.	<i>M</i>	<i>SD</i>
Do you use tobacco products	22	Yes = 6 No = 16		
Cigarettes/Cigars Frequency	2	Daily = 2 Weekly = 0 Monthly = 0 Occasionally = 0		
Average amount consumed on a day of use	3		5.00	4.58
Smokeless/Chewing Tobacco Frequency	4	Daily = 4 Weekly = 0 Monthly = 0 Occasionally = 0		
Average amount consumed on a day of use	4		26.31	47.82
Nicotine patch/gum Frequency	1	Daily = 1 Weekly = 0 Monthly = 0 Occasionally = 0		
Average amount consumed on a day of use	1		12.50	-
Do you use any caffeine products or over the counter supplements?	22	Yes = 20 No = 2		
Caffeine products Frequency	19	Daily = 18 Weekly = 0 Monthly = 0 Occasionally = 1		
Average amount consumed on a day of use			6.05	21.89
Protein powder frequency	8	Daily = 6 Weekly = 0 Monthly = 1 Occasionally = 1		
Average amount consumed on a day of use	8		30.31	43.88
Multi-vitamin Frequency	6	Daily = 5 Weekly = 1		

		Monthly = 0		
		Occasionally = 0		
Average amount consumed on a day of use	6		1.08	0.20
Do you use any over-the-counter (OTC) or prescription medications?	22	Yes = 8 No = 14		

Table A4. Phase 2 Descriptive Statistics for Flight Duties

Variable	<i>n</i>	Mean	SD	Min	Max
On the controls time (last year)	84	133.13	74.77	14.00	450.00
On the controls time (last 90 days)	82	43.13	26.74	0.00	150.00
On the controls time (last 30 days)	82	19.82	13.68	0.00	50.00
^a How many hours do you fly for military related duties?	81	8.93	12.19	0.00	60.00
^a How many hours do you fly for military related duties? (simulated)	76	3.26	4.64	0.00	30.00
^a How many hours do you work?	83	41.92	20.88	1.00	80.00
^a How many flights do you perform?	82	2.84	6.60	0.00	60.00
^a Average length of a typical flight (hours)	83	3.08	1.12	0.00	6.00
^a What percentage of your military flying occurs during: Day	82	54.76	25.85	0.00	100.00
^a What percentage of your military flying occurs during: Night unaided	76	6.99	7.67	0.00	50.00
^a What percentage of your military flying occurs during: Night with NVGs	74	36.35	22.55	0.00	90.00

Note. ^a indicates data were obtained from the preceding three months.

Table A5. Phase 2 Descriptive Statistics for Medial Symptoms and Waivers

Variable	<i>n</i>	Frequency
Frequent or Severe Headache	84	Yes = 10 No = 74
Car, Train, Sea, Simulator, or Air Sickness	84	Yes = 9 No = 75
A Period of Unconsciousness or Concussion	84	Yes = 7 No = 77
Have you had a recent sinus infection	84	Yes = 5 No = 79
Anxiety or depression	84	Yes = 5 No = 79
Been issued a waiver for behavioral health	83	Yes = 2 No = 81
Been grounded for a medical condition	83	Yes = 11 No = 72

Table A6. Phase 2 Descriptive Statistics for Health Behaviors

Variable	<i>n</i>	Freq.	<i>M</i>	<i>SD</i>
Do you use tobacco products?	82	Yes = 19 No = 63		
Cigarettes/Cigars Frequency	10	Daily = 5 Weekly = 1 Monthly = 3 Occasionally = 1		
Average amount consumed on a day of use	10		1.33	1.73
Smokeless/Chewing Tobacco Frequency	15	Daily = 8 Weekly = 5 Monthly = 2 Occasionally = 0		
Average amount consumed on a day of use	14		0.75	0.65
Nicotine patch/gum Frequency	0	Daily = 0 Weekly = 0 Monthly = 0 Occasionally = 0		
Average amount consumed on a day of use	0		-	-
Do you use any caffeine products or over the counter supplements?	80	Yes = 73 No = 7		
Caffeine products Frequency	73	Daily = 55 Weekly = 14 Monthly = 0 Occasionally = 4		
Average amount consumed on a day of use	74		10.35	17.23
Protein powder frequency	23	Daily = 14 Weekly = 6 Monthly = 1 Occasionally = 2		
Average amount consumed on a day of use	24		18.44	20.08
Multi-vitamin	22	Daily = 19		

Frequency		Weekly = 2 Monthly = 1 Occasionally = 0		
Average amount consumed on a day of use	20		1.15	0.37
Do you use any over-the-counter (OTC) or prescription medications?	80	Yes = 17 No = 63		

Appendix B. Instruction sheet used by participants to fill out the daily logbook.

Aviator Daily Logbook

Date: _____

Time in Bed: _____ Time Awake: _____

Did you sleep through the entire night? Y / N

If no, briefly state why: _____

Rate your quality of sleep (1 is lowest level of quality and 5 is the highest quality of sleep).

Very Bad 1 2 3 4 5 Very Good

Did you take a nap today?: Y / N Length (in minutes): _____

Did you perform flight duties today?: Y / N If so, please specify:

Airframe Model	Time of Flight	
	Start	End

Did you engage in vigorous physical activity (increased heart rate and breathing) for at least 20 minutes today? Yes / No

If you use tobacco products, please indicate the type and frequency used today.

Product	Frequency
Cigarettes/Cigars	
Smokeless/Chewing Tobacco	
Vaping/e-cigarette	
Nicotine patches / gum	

If you use caffeine or supplements, please indicate the type and frequency used today.

Product	Frequency
Caffeine products (e.g. NOS [16 oz], Red Bull [8.46 oz], Coffee [8 oz], Soda/Soft Drink [12 oz], gum)	
Protein powder	
Multi-vitamin	
Other (Specify): _____	



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